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ABSTRACT

Four successful mathematics and science teacher retraining programs are described. The programs were based on identified local teacher shortages and continued as long as the need existed. Trainers had a thorough mastery of context and method and were able to relate to the adult learner. Trainees were experienced and successful teachers from other subject areas with established classroom management skills who had an aptitude and desire to learn and teach mathematics and science. Effective programs had close cooperation with local school districts, state education agencies, and institutions of higher education. Trainees were provided opportunities to practice teaching with a master teacher, beginning with short period of teaching relatively easy subject matter, and gradually progressing to longer periods of teaching more complex content. Initiating agencies in successful programs monitored the progress of individual trainees and assumed a nuturing role in regard to their development as mathematics and science teachers. (JD)

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Retraining Programs to Alleviate Teacher Shortages in Mathematics and Science

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- documenting educational problems of the Region and sharing the information both with member states and other R & D producers;
- identifying R & D products potentially useful for solving the documented problems and sharing information about these with member states;
- providing R & D technical assistance and training which may include adapting existing R & D products, to lessen documented problems of the Region; and
- continuing to produce R & D projects of national significance in the areas of Lifelong Learning, School/Family Relations, Basic Skills, and others that may be identified.

Information about AEL projects, programs and services is available by contacting the Appalachia Educational Laboratory, P. O. Box 1348, Charleston, West Virginia 25325.

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To the Reader:

This is the fourteenth in a series of AEL Occasional Papers, produced in the past five years. The paper is based on a short-term R & D project conducted by AEL with the Ohio Department of Education during 1983-84. The purpose of the project was to identify and describe promising programs operated within and outside of Ohio to alleviate mathematics and science teacher shortages.

The Ohio Department of Education projected future shortages of mathematics and science teachers, particularly in such advanced courses as trigonometry, calculus, chemistry, physics and earth science. The Department asked AEL to search for successful teacher retraining programs inside or outside Ohio in those areas of need. Additionally, the Department asked AEL to identify institutions of higher education in Ohio that were interested in working with the Department to retrain teachers.

The focus of the project was to describe the factors relating to the success of existing programs and then to recommend to the Department guidelines for the design of equally successful programs in Ohio.

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EXECUTIVE SUMMARY

Recent studies have projected shortages of mathematics and science teachers. While shortages are expected to seriously affect the science and mathematics curriculum at all grade levels, teacher shortages will be greatest for advanced courses at the secondary level. The shortages could have a severe effect on the educational system because well-qualified mathematics and science teachers in sufficient numbers are needed to prepare students for their future roles at work, at the polls and in the consumer society.

All states now have or project shortages in the supply of mathematics and science teachers. In most states, teachers are leaving or retiring from the profession, while fewer students are seeking to enter the teaching profession. Even as teachers are leaving their jobs, experts are projecting an increase in demand for teachers. For example, a significant increase in elementary school enrollments is forecast for the late 1980's. Demand for qualified teachers will increase further as states bolster their graduation requirements in mathematics and science.

States are using two major stategies for alleviating teacher shortages: financial incentive programs and new training or retraining programs. To support these initiatives, states have drawn upon federal funding and have worked with local school districts to remedy the shortages.

Over half of the states have targeted their resources for the retraining of teachers from other subject areas for service in mathematics or science. The operationalization of such retraining programs varies. Some are initiated by institutions of higher education, some by LEA's. Programs may be either short-term, intensive or long-term, non-intensive in nature.

Several success factors have been identified across all efforts. Effective programs were based upon needs identified or projected for local school districts and were designed to continue as long as the need existed. In most effective programs, coordinators took responsibility for program success. Program success was dependent upon the identification and careful selection of capable trainers and trainees, in some cases through the administration of an aptitude test. Instructors with a known ability to relate to adult learners contributed to program success. Programs which achieved success had coordinators who assumed a nurturing role (in regard to participants) throughout the existence of the program. Effective programs were characterized by close cooperation among the participating agencies. The identification of one person to represent each agency seemed to facilitate this successful interagency cooperation. Keeping the group of trainees together throughout the program seemed to foster a mutual support group. Practice teaching which involved working with experienced teachers and gradually progressing from easy to more advanced subject matter allowed trainees the necessary experience base to learn content and methods. Group cohesion and practical learning situations seemed to contribute to program success.

INTRODUCTION

The Appalachia Educational Laboratory, Inc. (AEL) conducts research and development (R & D) and provides R & D services to educational agencies in its service region. This region includes Alabama, Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia.

One aspect of the Laboratory's R & D service to member-states is jointly-sponsored, short-term projects with state departments of education (SDE's). This project-oriented R & D is typically a collaborative effort designed to meet expressed educational needs of AEL's clients in SDE's.

In the summer of 1982, AEL and the Ohio SDE agreed to conduct a study that would address the problem of teacher shortages in mathematics and science, and recommend possible ways to alleviate those shortages. From the outset, the Ohio SDE was interested in retraining out-of-field teachers as a solution measure.

The purposes of the project were: (a) to describe the extent of teacher shortages in mathematics and science in the nation and in Ohio, (b) to describe solution strategies used across the country, (c) to collect in-depth information regarding successful approaches to remedying teacher shortages, (d) to identify conditions which seem to account for the success of the approaches, (e) to identify relevant information resources and (f) to make recommendations to the Ohio SDE for working with local education agencies (LEA's) to alleviate teacher shortages.

Statement of the Problem

The Ohio SDE was concerned that in future years there may be shortages of teachers in the subject areas of mathematics and science (particularly for advanced courses--calculus, trigonometry, chemistry, and physics). The SDE wanted to learn what other states were doing to alleviate this problem. SDE staff were particularly interested in knowing about successful teacher retraining programs because such programs would enable teachers to move from oversupplied subject areas to the undersupplied areas of mathematics and science.

The problem then was one of documenting in detail successful programs (particularly retraining programs) that could be used in Ohio to diminish teacher shortages. The project, further, was to describe the conditions under which such programs are successful and to make recommendations to the SDE regarding ways in which it might initiate similar programs in LEA's of the state.

Review of the Literature

The following sources were consulted in preparing this report.

(a) ERIC database,
(b) journal articles,
(c) personnel in SDE's and LEA's with promising practices for alleviating teacher shortages, and
(d) educational researchers/practitioners known to AEL or to the Ohio SDE as expert on this topic.

By searching the above sources, it was learned that there were no definitive studies on the topic. However, the literature does sketch the dimensions of teacher shortages nationwide, and it offers a number of examples of effective solution strategies.

The Nationwide Shortage

Today, the American educational system is experiencing a serious shortage of mathematics and science teachers--a situation that compares to the crisis of confidence in mathematics and science education in 1957. As many of the most qualified teachers of mathematics and science leave precollegiate teaching, and as more and more mathematics and science teacher graduates opt for positions in business and industry rather than in teaching, our educational system and society in general suffer.

A qualified and fully staffed mathematics and science faculty is needed in elementary and secondary schools to identify, prepare and challenge individuals of high ability and to provide basic instruction to all students who will need it to function as workers, voters and consumers in their adult years. While the United States has maintained a steady supply of highly qualified, innovative scientists, this can only continue to be the case if the same level of precollegiate mathematics and science instruction is maintained. And as we enter a technological age, Americans on the job will likely be required to solve problems that demand mathematical and scientific skills. At the polls, people will need to cast ballots reflecting knowledge of issues relating to nuclear energy, pollution, defense and space exploration. Increasingly, adults will be required to make informed decisions regarding the selection of goods, services and ideas of a scientific nature. In short, a higher degree of mathematical and scientific literacy will be required of adults in the future. An appropriately informed citizenry will be required to support a technologically advancing economy.

An interesting irony is taking place. American success and progress in science and mathematics have contributed to the present shortage of teachers. The educational system's emphasis on science and mathematics has led to the development of a significant computer industry. Many people who would otherwise have become mathematics and science teachers are now entering the computer industry, resulting in a dearth of qualified science and mathematics teachers in the public school system. The shortage of teachers in these subject areas is nationwide and significant.

A shortage of science teachers has been reported in all areas of science instruction across the nation. A study conducted by the Iowa State Department of Public Instruction has identified science teacher shortages nationally. Table 1 summarizes the status of teacher supply by state and by advanced science and math courses in 1983.

Estimated Supply of Secondary Biology, Chemistry, Physics, General Science, Earth Science, and Mathematics Teachers by State in 1983

State	Biology	Chemistry	Physics	General	Earth	Math
Alabama	slight surplus	shortage	critical shortage	adequate	shortage	no response
Alaska	adequate	adequate	adequate	adequate	adequate	adequate
Arizona	adequate	adequate	adequate	adequate	adequate	shortage
Arkansas	adequate	shortage	shortage	shortage	adequate	shortage
California	shortage	shortage	adequate	shortage	adequate	critical shortage
Colorado	shortage	shortage	shortage	shortage	shortage	shortage
Connecticut	adequate	shortage	critical shortage	adequate	shortage	shortage
Delaware	slight surplus	adequate	adequate	slight surplus	adequate	shortage
District of Columbia	adequate	critical shortage	critical shortage	adequate	adequate	critical shortage
Florida	adequate	shortage	critical shortage	adequate	shortage	shortage
Georgia	adequate	shortage	shortage	shortage	adequate	adequate
Hawaii	shortage	shortage	critical shortage	adequate	shortage	shortage
Idaho	slight surplus	shortage	shortage	adequate	adequate	shortage
Illinois	adequate	critical shortage	critical shortage	shortage	shortage	critical shortage
Indiana	shortage	critical shortage	critical shortage	critical shortage	critical shortage	critical shortage
Iowa	slight surplus	shortage	critical shortage	adequate	shortage	critical shortage
Kansas	slight surplus	shortage	critical shortage	adequate	shortage	critical shortage
Kentucky	adequate	critical shortage	critical shortage	critical shortage	critical shortage	critical shortage
Louisiana	adequate	shortage	critical shortage	adequate	shortage	shortage
Maine	adequate	shortage	shortage	adequate	adequate/shortage	shortage
Maryland	slight surplus	shortage	critical shortage	critical shortage	critical shortage	critical shortage
Massachusetts	surplus	adequate	adequate	surplus	surplus	adequate
Michigan	adequate	adequate	shortage	adequate	adequate	shortage
Minnesota	surplus	adequate	adequate	adequate	shortage	adequate

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Mississippi	adequate	shortage	critical shortage	adequate	adequate	critical shortage
Missouri	shortage	critical shortage	critical shortage	shortage	critical shortage	critical shortage
Montana	shortage	shortage	shortage	adequate	adequate	shortage
Nebraska	adequate	shortage	shortage	adequate	shortage	shortage
Nevada	slight surplus	shortage	shortage	no response	adequate	critical shortage
New Hampshire	adequate	critical shortage	critical shortage	critical shortage	shortage	critical shortage
New Jersey	no response	no response	no response	no response	no response	no response
New Mexico	slight surplus	adequate	shortage	surplus	critical shortage	slight surplus
New York	adequate	shortage	critical shortage	shortage	shortage	shortage
North Carolina	adequate	critical shortage	critical shortage	shortage	shortage	critical shortage
North Dakota	slight surplus	adequate	shortage	adequate	adequate	shortage
Ohio	adequate	critical shortage	critical shortage	shortage	shortage	adequate
Oklahoma	adequate	adequate	adequate	shortage	shortage	shortage
Oregon	adequate	cxritical shortage	critical shortage	adequate	critical shortage	shortage
Pennsylvania	slight surplus	critical shortage	critical shortage	adequate	shortage	shortage
Rhode Island	slight surplus	adequate	adequate	adequate	no response	adequate
South Carolina	shortage	critical shortage	critical shortage	shortage	critical shortage	critical shortage
South Dakota	adequate	critical shortage	critical shortage	adequate	shortage	critical shortage
Tennessee	adequate	shortage	shortage	adequate	adequate	shortage
Texas	surplus	critical shortage	critical shortage	no response	shortage	shortage
Utah	adequate	shortage	shortage	adequate	adequate	shortage
Vermont	adequate	shortage	critical shortal	shortage	shortage	shortage
Virginia	surplus	shortage	shortage	surplus	critical shortage	shortage
Washington	adequate	shortage	shortage	adequate	shortage	shortage
West Virginia	no response	no response	no response	no response	no response	no response
Wisconsin	slight surplus	shortage	critical shortage	shortage	adequate	adequate
Wyoming	adequate	adequate	adequate	adequate	adequate	adequate
America Samoa	shortage	critical shortage	critical shortage	shortage	shortage	shortage
Puerto Rico	slight surplus	critical shortage	critical shortage	adequate	critical shortage	no response

Source: State Department of Public Instruction: Iowa

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In physics, 42 states reported a shortage of teachers, with 27 states indicating a critical shortage. For chemistry, 40 states reported a shortage of teachers with 15 states having a critical shortage. In the area of earth science, 33 states had a shortage of teachers with 9 states reporting a critical shortage. In mathematics, 41 states reported teacher shortages with 15 states having critical shortages.

The future supply of teachers does not seem any more positive. The proportion of freshmen students preparing to enter the teaching profession is small (2 percent of all freshmen plan to teach in secondary schools and 3.5 percent for elementary schools). At the University of California at Berkeley, for example, less than one percent of entering freshmen were interested in teaching. And the proportion of science and mathematics majors interested in teaching was exceedingly small (Phi Delta Kappan, September 1982).

The number of students completing degrees in mathematics education has steadily decreased during the past decade. Table 2 summarizes the number of students completing bachelor's, master's and doctorates in the past ten years.

Table 2

Number of Students Receiving Degrees
in Mathematics Education
1971-1981

Year	Bachelor's	Master's	Doctorates
1971	2,217	782	49
1972	2,425	764	51
1973	2,489	733	52
1974	2,037	828	59
1975	1,938	760	64
1976	1,358	746	55
1977	1,156	663	49
1978	1,048	598	39
1979	850	483	42
1980	762	512	38
1981	798	372	30

Source: National Center for Education Statistics
(As presented in USA TODAY, February 10, 1983)

The number of earned bachelors degrees decreased from 2,217 in 1971 to 798 in 1981 (a decline of 64%). Similarly, the number of people who completed a master's degree in mathematics education fell from 782 to 372 (a decrease of 52%).

Since 1972, there's been a 77 percent decline in the number of secondary-level mathematics teachers prepared in 600 teacher-training programs in the nation. Only 55 percent of those who did graduate from teacher training programs during that time actually entered the teaching profession.

An NEA survey estimated that only 8,000 American students out of nearly one million 1979-80 college graduates completed a program to teach mathematics or a natural or physical science. Based on past percentages, probably fewer than 6,000 of these individuals would decide to teach (Phi Delta Kappan, September 1982).

Data from individual states dramatize the prospect of future teacher shortages in mathematics and science. For example, in California in the spring of 1982, there were 400,000 students in public four-year institutions. Only 97 of these students were preparing to become secondary school mathematics teachers, and only 174 were pursuing training as secondary school science teachers. Of the 30,000 students at the University of California at Berkeley campus, only one was enrolled in the mathematics teacher education program and five in the science program in 1982 (Phi Delta Kappan, September 1982).

The Florida Department of Education estimates that its colleges and universities will graduate only about 20 mathematics teachers a year for the next five years. There will be an annual need for about 325 mathematics teachers during that period (USA TODAY, February 10, 1983).

In Iowa, the number of mathematics graduates decreased from 234 in 1970 to 60 in 1979--a decline of 74 percent. During that time, the number of vacancies fluctuated between 200 and 250 per year. Smaller school districts were most affected by the shortages (School Science and Mathematics, January 1982).

In New Hampshire, only one college graduate in 1982 planned a career in mathematics teaching (Christian Science Monitor, July 12, 1982). In New Jersey, 19 of 21 county offices reported that they could not find fully certified mathematics instructors (The Record, August 7, 1980). In New York, the country's second most populous state, only 32 graduates in 1982 planned to teach junior or senior high school mathematics.

The State of Ohio expects to produce 140 mathematics teachers and 165 science teachers in the next four years and expects about 100 openings in both fields. Still, the state education agency is concerned that there may

be shortages of teachers in both fields because graduates are so employable outside of education. The state education agency believes there is a need to graduate two teachers for every mathematics or science vacancy to avert shortages (Education Week: A Special Report, Vol. II, n. 39, July 27, 1983, p. 33).

The state of Washington similarly has experienced a decline in the number of graduates in mathematics and science. In the state of Washington, between 1974 and 1978, the number of students receiving certificates as mathematics teachers declined from 125 to 54, a decline of 77 percent. In science fields the number of new certificates declined from 122 to 86, a decrease of 29 percent. In 1978, science education graduates were only 70 percent of the number graduated in 1974. In 1978, mathematics graduates were only 40 percent of the number graduated in 1974. Still, the demand for teachers in both areas greatly increased during those years. The demand for science teachers rose 35 percent, and the demand for mathematics teachers increased by 76 percent (American School Board Journal, September 1982).

Uncertified Teachers in the Present Workforce

The picture of teacher shortages worsens when considering the large percentages of newly-employed mathematics and science teachers that are unqualified. Table 3 summarizes the situation by regions of the United States.

Table 3

Percentage of Newly-Employed, But Unqualified Mathematics and Science Teachers

Census Region	1981-1982
Pacific States	84%
Mountain States	43%
West North Central States	43%
West South Central States	63%
East North Central States	32%
East South Central States	40%
Northeastern States	9%
Middle Atlantic States	46%
South Atlantic States	50%
NATIONWIDE	50%

Source: James Shymansky, National Science Teachers Association, Washington, D.C., 1982.

Table 3 illustrates that nearly half or more of the newly-employed teachers in mathematics and science during 1981-82 from most regions of the country are unqualified to teach in those subject areas. The percentage of newly-employed mathematics and science teachers who were unqualified included: Pacific states (84%), West South Central states (63%), and the South Atlantic states (50%). An exception is the Northeastern section of the United States where only nine percent of the mathematics and science teachers were unqualified.

Commenting on the results of employing underqualified mathematics teachers, math consultant Joe Hoffman of the California Department of Education notes (USA TODAY, February 10, 1983):

> We're really concerned that teachers who are not well prepared in math, and who do not understand the big picture of math, tend to fragment the skills. You learn one skill totally out of context with anything else that's learned.

The Teacher Shortage as Exodus

One of the reasons that there is a shortage of teachers of mathematics and science is that many of these teachers are leaving the teaching profession for positions with business and industry. Elizabeth Useem, a sociologist at Northeastern University, studied the schools of Northern California's Silicon Valley. Useem found that 60 percent of the teacher respondents were "seriously considering" the possibility of leaving the teaching profession for higher paying jobs in high technology. In a similar study of the Boston area, Useem found that 47 percent of the mathematics and science teachers were planning or very seriously considering leaving their teaching positions. Table 4 illustrates the career plans of science and mathematics teachers in Useem's Boston study.

Table 4

Future Career Plans of Secondary Mathematics and Science Teachers in Seven Boston Area School Systems

	Percentage Response
Planning a permanent career in teaching and/or educational administration	41
Planning to leave teaching	25
Very seriously considering leaving teaching for another field	22
May be laid off	12

Respondents planning to leave teaching were asked to explain their reasons for doing so. Teachers referred to "widespread demoralization" related to job dissatisfaction and low salaries as motives for seeking

employment in business and industry. Teachers planning to leave the profession made the following comments (as reported by Useem, 1982):

> "I'm tired of the long hours and low pay. Nobody except teachers care about the education of children."
>
> "Teaching is now a dead-end occupation."
>
> "I'm tired of teaching and the future looks bleak."
>
> "The teaching environment becomes less pleasant each year."
>
> "I love teaching but it's wearing me out. There are too many alienated kids to face everyday."
>
> "Working conditions are deteriorating. I want to leave Massachusetts and its anti-education attitude."
>
> "Teaching is a luxury I can no longer afford."
>
> "There is no room for growth, no reward for excellence in teaching. Salaries do not keep pace with inflation."

It is estimated that, if the present exodus of qualified science and mathematics teachers from secondary schools continues, the nation will have a net loss of 35 percent of teachers by 1992 (Sarah Klein, President, National Science Teachers Association, Testimony before Committee on Labor and Human Resources, U.S. Senate, 1982).

The Increasing Demand for Science and Mathematics Teachers

While the supply of mathematics and science teachers is decreasing (in 1980, the supply of mathematics teachers was only 78 percent of the demand), the demand for teachers will be increasing. Many of the teachers in these subject areas were hired in the 1950's and 1960's to teach the "baby boom" students. These experienced teachers will arrive at retirement age in the 1980's and 1990's. By 1995 at least 40 percent of the present 200,000

mathematics and science teachers will retire. An upturn in elementary school enrollments is expected to begin in 1983. This current baby boom will reach the elementary schools by 1989. Total enrollment was expected to increase by about two percent, or by about 400,000 children annually for the next 15 years.

There is also a trend to increase graduation requirements in science and mathematics which will likely worsen the shortage. It is estimated that if schools raised their requirements by one year in both mathematics and science, an additional 68,000 teachers would be required nationally.

At the present time there are approximately 200,000 teachers of mathematics and science in the country. Experts agree that 60,000 additional teachers are needed to replace unqualified or minimally qualified teachers.

The combined factors of retiring teachers, demographic changes, and increased graduation requirements could mean that an additional 300,000 new teachers in mathematics and science will be needed by 1995.

SOLUTION STRATEGIES

Since 1980, states have addressed their mathematics-science program needs in a number of ways. Twenty-two states have initiated financial-incentive programs to increase the number of mathematics and science teachers while 27 states have instituted training or retraining programs for the same purpose. Table 5 summarizes initiatives by states to alleviate teacher shortages.

Table 5

Summary of 50-State Survey:
Status of Teacher-Related Initiatives
and Graduation Requirements
1983

The chart below is based on telephone interviews conducted by Education Week staff writers with mathematics and science specialists in state education departments and governors' offices, legislative-affairs specialists, and spokesmen for teachers.

State	Financial-Incentive Programs	Training/Retraining Programs	Grad. Req. Changed Since 1980	Years Required	
				Math	Science
Alabama	Yes	No	Yes	2	1
Alaska	No	No	No	1	1
Arizona	Yes	Yes	Yes	2	2
Arkansas	Yes	No	Local*	-	-
California	Yes*	Yes	Local	(2)	(2)
Colorado	No	No	Local	-	-
Connecticut	Yes	No	Local	-	-
Delaware	No	No	No*	1 (2)	1 (2)
Florida	Yes	Yes	Yes	3	3

Notes: (F) indicates that an initiative was considered in the legislature this year but failed to pass; * indicates that an initiative is under consideration; ** indicates a requirement for college-bound students only; the numbers in parenthesis indicate proposed requirements; "Local" indicates that requirements are now set at the district level.

Table 5 (continued)

Georgia	Yes	No	No*	1	1
Hawaii	No	No	No	2	2
Idaho	No	No	Yes	2	2
Illinois	Yes*	No	Local*	(2)	(1 or 2)
Indiana	Yes	Yes	Yes	2	2
Iowa	Yes	Yes	Local	-	-
Kansas	No	No	No*	1 (2)	1 (2)
Kentucky	Yes	No	No*	2 (3)	2
Louisiana	Yes*	No	No	3	2
Maine	(F)	Yes	Local	-	-
Maryland	(F)	Yes	No*	2	2
Massachusetts	No	Yes	Local	-	-
Michigan	No	Yes*	Local	-	-
Minnesota	(F)	Yes	Local	-	-
Mississippi	Yes	Yes	No	1	1
Missouri	No	Yes	No	1 (2)	1 (3)
Montana	No	Yes	No*	2	1
Nebraska	No	No	Local	-	-
Nevada	No	No	Yes	2	1
New Hampshire	(F)	No	No*	1 (2)	1 (2)
New Jersey	Yes*	Yes	No	2	1
New Mexico	No	Yes	Yes	2	2
New York	Yes*	Yes*	Yes	2	1*
North Carolina	Yes*	Yes	No	2	2
North Dakota	No	Yes	Yes	2	1

Table 5 (continued)

Ohio	No	No	Yes	2	1
Oklahoma	No	Yes	Yes	2	2
Oregon	No	No	No	1	1
Pennsylvania	Yes*	Yes*	No*	1 (3)	1 (3)
Rhode Island	No	No	Yes*	3**	2**
South Carolina	No	No	No*	2	1
South Dakota	Yes	No	Yes	2	2
Tennessee	No	No	Yes	2	2
Texas	No	Yes	No	2	2
Utah	Yes	Yes	No*	1	1
Vermont	Yes	No	Local*	-	-
Virginia	No	Yes	No*	1	1
Washington	Yes	Yes	Yes	2	2
West Virginia	No	Yes	Yes	2	1
Wisconsin	Yes*	Yes*	Local	-	-
Wyoming	No	Yes	Local	-	-

Sources: Education Week, National Association of Secondary School Principals (1980 Data)

More than 20 percent of science education teachers took university coursework, and twenty percent of computer science teachers attended workshops (see Figure 1).

Some positive action has been taken to improve the qualifications of existing mathematics and science teachers. For example, many mathematics and science teachers have also updated their skills through workshops and university coursework during the past three years. Figure 1 summarizes by subject area the percentage of teachers who sought to update their skills through enrollment in workshops and in university courses from 1981-1983.

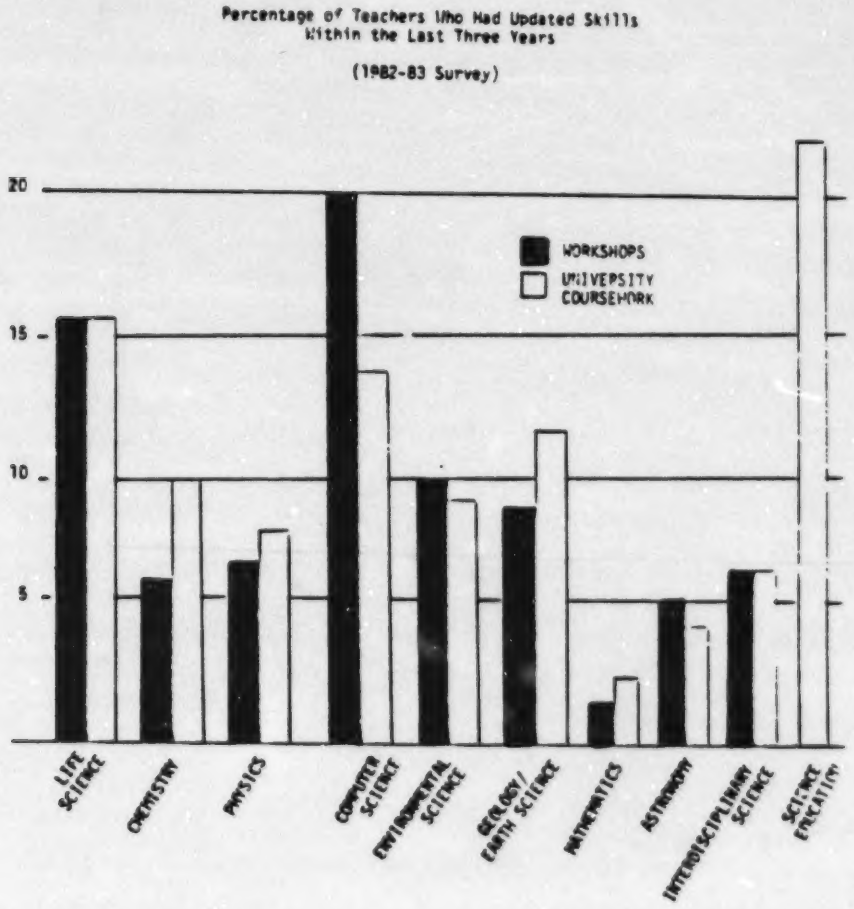

Figure 1

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A number of approaches to alleviating the shortage of mathematics and science teachers have been employed. Some approaches have been initiated in the U.S. Congress, others in the state legislatures, and still others in local school districts.

Initiatives in the U.S. Congress

The shortage of qualified mathematics and science teachers has drawn the attention of the Reagan Administration. President Reagan has recently proposed that $70 million be funded for new programs to upgrade math and science education. Fifty million dollars would be available to states in block grants through the U.S. Department of Education. These funds would be used to provide scholarships to increase rapidly the supply of high school math and science teachers.

Under the plan, states would receive grants based on their populations of secondary school students. The states would then give funds to school districts and private schools for scholarships of up to $5,000 a person for a one-year retraining program. The states would not need to match the funds, and the Education Department would not specify the terms of agreements between school districts and scholarship recipients. However, states would be limited to four percent administrative costs in their allotments to local school districts.

Another $20 million in National Science Foundation funds would go for retraining junior and senior high school science teachers and for recognizing those teachers who are outstanding. It is predicted that 10,000 teachers a year could be trained under the National Science Foundation's plan.

Nineteen million dollars of the $20 million NSF proposal would provide grants to colleges for retraining workshops, seminars, or full-time courses. The colleges would have to match the money dollar for dollar.

In the U.S. Congress, H.R. 1310 is now being considered. The bill consolidated two bills introduced by Representative Carl Perkins and Representative Don Fuqua and is designed to reduce the math-science teacher shortage. As approved by the House Education Committee, H.R. 1310 would authorize $300 million for new grants to improve mathematics-science instruction during 1984. Two hundred fifty million dollars would go to state education agencies and local school districts. One million dollars of the SEA funds would be for faculty retraining and equipment. The remaining $50 million would be earmarked for grants to colleges and universities. Seventeen and one-half million of these dollars would be for summer institutes to improve teachers' skills in science and mathematics. In 1985 the bill would authorize "such sums as may be necessary."

Initiatives at the State and Local Levels

A variety of initiatives has been used at the local level including: increasing funds for teacher training, providing teacher aides and such supportive resources as science teaching centers, laboratories, and better science curricula; exempting science and mathematics teachers from mundane tasks; modifying state certification requirements to permit graduates in mathematics and science to teach at the secondary level without having to take professional education preparation courses while in college; transferring mathematics specialists into elementary schools; creating part-time teaching positions so that qualified individuals not currently in the work force can teach; and offering 12-month contracts to mathematics and science teachers and guaranteeing them summer employment in private industry.

However, the most promising measures are retraining and recertification programs with financial incentives. The state of Kentucky has begun a program to alleviate mathematics and science teacher shortages through teacher retraining programs. The state of New York has initiated major related legislation. The cities of Fairfax, Houston, and Philadelphia have also begun retraining programs. Westfield State College in Massachusetts is currently retraining teachers.

Former Kentucky State Superintendent, Raymond Barber secured legislation that provided for a $610,000 loan/scholarship program for undergraduates, during 1982-84, in the state's 23 colleges that offer teacher education programs. Students receive three-year loans of $2,500 per year in return for a promise to teach mathematics or science in Kentucky schools. For every year they teach, one year of their loan becomes a scholarship. If the teacher does not continue teaching, they must repay the loan at the current Treasury Bill rate of plus three percent (American School Board Journal, September 1982). Seventy-five undergraduates enrolled in the program in the fall of 1982.

During the summer of 1983, 20 certified teachers with degrees in fields other than mathematics or science will become eligible for $833 per-year retraining loans. The teachers need to have a major in an area other than mathematics and science and to have been admitted to a teacher education program. The Kentucky SDE will screen applications and select the teachers to be awarded the scholarships which are for full-time summer study for three years. Applicants' eligibility is based on their GPA, GRE, or NTE scores, letters of recommendation, estimated hours required for certification, and registration as a full-time student.

In New York state several legislative proposals were made to improve the elementary and secondary programs in mathematics and science. One proposed amendment to the Education Law provided for a minimum of 50 part-time Regents graduate fellowships for first-time doctoral students in mathematics and the physical and biological sciences. Under the plan, graduate fellows would receive a maximum of $2,000 per year for two years with a $3,000 stipend for living expenses. For 30 of the fellowships, teachers whose positions had been eliminated the previous two years would be given preference. The fellowships could be used at any New York institution of higher education with a registered program for the preparation of mathematics and science teachers. For the first year of the program $200,000 is being requested, with $400,000 requested for each of the next four years.

In a very promising local education agency effort, the Fairfax (VA) County Schools have initiated a program to reduce the shortage of math and science teachers for high schools. After two years of planning, the 2 1/2-year program is being administered in conjunction with Northern Virginia Community College (NVCC) and George Mason University. Another 2 1/2-year program is scheduled to begin in the summer of 1983. Twenty-eight teachers are enrolled in the program. Most of them are high school and junior high teachers, but some are elementary teachers. The program participants are previously certified in such areas as art and music. The program participants spend one year studying math at NVCC and then move to George Mason University to complete the final course in the certification process (The Alexandria Gazette, October 18, 1982). The program involves such courses as calculus and analytic geometry, linear algebra, differential equations and computer science.

The program was initiated by the Fairfax County Schools which screens the candidates. The following criteria for selection are implemented:

- a minimum of four (4) successful, consecutive years of full-time teaching experience in the Fairfax County Public Schools;
- a recommendation from the applicant's principal;
- a commitment to complete successfully all courses needed for full mathematics certification; and
- successful completion of a placement examination.

In regard to the first requirement, Dr. Sylvia Auton of the Fairfax County Schools comments: "It's better to train the people we have who are proven in the classroom and have a commitment to our school system." The system supports qualified teachers through a budgeted tuition assistance fund and hopes to obtain state funding to establish a research component and to hire a "master" mathematics teacher to conduct related applications seminars.

With funding from the State Department of Education, the Fairfax County System plans to evaluate the overall effectiveness of the program by:

1. conducting pre- and post-surveys of applicants regarding their interest and motivation before the training and a year after their placement in a mathematics position;
2. surveying school-based administrators' and mathematics curriculum specialists' evaluations of the level of mathematics competence and classroom strategies of the program participants.

There were a total of 43 teachers being retrained in two groups. Approximately one-third of the teachers have dropped out of the retraining program. Four teachers have completed the program and have been placed. A third group may be retrained if there are sufficient applicants.

While no evaluation data are currently available, the Fairfax County Schools plan to work with the National Council of Teachers of Mathematics to survey the retrained teachers and their principals once they have been placed. The purpose of the survey is to identify problems encountered that could be solved in the redesign of the program. The program also provides for classroom observations of the teachers.

Dr. Auton recommends that several measures be taken to ensure program success. Participation in the program, for example, needs to be voluntary. Also, it is important to recruit experienced teachers. Their maturity will help them achieve success as retrained mathematics teachers, since they are already capable in classroom management and discipline. It is essential to maintain close working relationships between the school district and the retraining institution. In the Fairfax County Schools, one person is responsible for working with the university professors involved in the program and for maintaining communications with all teachers being retrained. The selection of participating university instructors is also important. It is essential that the instructor be able to work comfortably with adults. The program also needs to allow opportunities for the teachers being retrained to observe the classrooms of capable, experienced mathematics teachers. Finally, the Fairfax County Schools have also found it helpful to keep together the groups of teachers being retrained. As they stay together over time an esprit de corps and problem-solving capacity are developed, contributing to the success of the teachers. Finally, it is important that the initiating institution (the local school district) provide continuing nurturance of the program and not leave it to the university to carry out the program.

The Houston City Schools also has an incentive pay plan titled, "The Second Mile Plan," which addresses teacher shortages and other factors relating to instructional improvement. Through that plan, teachers who return to college to acquire certification in areas of critical teacher shortages (for example, in mathematics and science) are eligible for stipends. For each six-hour block of university coursework or each 72 hours of district-approved inservice training, the stipend is $300. If the courses are in areas of critical teacher shortages, the stipend is $400.

Mira Baptiste, Director of Staff Development, (American School Board Journal, September 1982, p. 24) commented:

> We can no longer look to the universities to define our needs or to fulfill them. We were looking to regain our control.... The universities can't even get people to come and make them stay in education. We know people are getting siphoned off even before they finish school.

Teachers apply for the stipend for which they qualify. Stipends are paid in one lump sum in June to teachers whose specialties are in short supply and to those in high priority schools.

There have been very encouraging results for the first three years of the Second Mile Plan. In specialties with significant teacher shortages, classroom vacancies decreased from 251 in August 1979 to 21 in August 1982, a decline of 91 percent. Additionally, teacher attendance at school increased from 95.6 percent to 96.1 percent during that time.

The Houston Public Schools' Second Mile Program is in its fifth year and will continue. Statistics about the program are not available outside the district, yet the program is deemed a success. More than $2 million a year is spent for this teacher incentive program. One of the major

indicators of success is that teacher turnover has decreased from 17 percent to 4 percent a year. In addition, teachers attendance has increased and teacher vacancies decreased. A new component of this merit-pay program has been added--that of teacher technologist. A teacher technologist is responsible for coordinating the use of technology at the school to which he or she is assigned. Trainers receive 300 hours of free inservice. A district representative says that the main factor in the program success is the availability of money. She recommends that any district interested in starting such a program should be certain of sufficient funding for a minimum of five years. A second recommendation is that there be a balance between group and individual rewards. For example, each year the research department establishes achievement goals for each school in the district. If the goal is attained, a $2,000 reward is divided among the faculty of the school. School excellence flags are given to successful schools. To promote attendance, the program allows teachers to sell back a maximum of five days of unused sick leave at $100 a day.

The Philadelphia Public Schools have recently initiated a three-year teacher retraining program for elementary mathematics. Begun in 1982, the program allows teachers to earn nine credits a year over three years to achieve state certification. Participants have to be teachers, already certified, in another area who have already completed a minimum of six semester hours in mathematics or mathematics education and who have served a minimum of three years in the Philadelphia School District. Participants also have to pass a mathematics aptitude test.

Two hundred eighty teachers applied for the retraining program. One hundred ten met the qualifications and sixty actually started retraining in May of 1982 (American School Board Journal, September 1982.)

Participants receive retraining at any of seven Philadelphia area colleges and universities. While participants pay their own expenses, they receive a one-third discount in tuition for one-half of the required 27 hours of retraining. The score on the mathematics Aptitude Test determines who is admitted to the program. Successful candidates who are assigned to a mathematics teaching position are issued a Commonwealth of Pennsylvania emergency certificate in mathematics. As is required of everyone in that position, nine semester hours of approved courses must be completed in order to qualify for an annual extension.

Twenty of the 60 people in the mathematics retraining program will graduate this spring with full certification. They will be eligible for the qualifying examination for replacement. There are sufficient mathematics vacancies for all 20 graduates to be placed. The remaining 40 people in the retraining program will graduate by the spring of 1985. At that time a second mathematics retraining program will begin. In addition, a science teacher retraining program will begin by the summer of 1984.

Dr. Tobin attributes the success of the program to its responsiveness to the need for well-trained science and mathematics teachers, to careful training by the seven participating universities, and to continuing communications between the district and the universities, allowing for the ongoing redesign of the program. Also, teachers in the retraining program, in their first practice experiences in mathematics instruction, have not been required to teach any subject more difficult than ninth grade algebra. Teachers will teach the more difficult mathematics courses after successful experience with the less difficult courses. One of the program administrators from the central office has taught one of the introductory

courses at a university, providing further linkage between the administrative and instructional components of the program. This liaison between the school district and the university is essential to program success, according to Dr. Tobin.

One difficulty of the program has been in the screening of applicants. Universities were asked to administer a mathematics aptitude test to applicants. Some universities were relatively lenient in terms of qualifying scores in the mathematics aptitude test. As a result some teachers who were admitted to the retraining program had difficulties mastering the content and subsequently dropped out of the program.

In Massachusetts, many teachers have been laid off because of the tax-cutting Proposition 2 1/2. Between October 1980 and October 1981, 8,748 full-time equivalent instructional positions were abolished. At the same time, the State is experiencing a shortage of qualified math and science teachers. Westfield State College is seeking to address both problems by providing a mathematics-science recertification program for teachers already certified in another field.

At present, 25 teachers from such diverse fields as English, music, and special education have enrolled in the recertification program. Participants pay as much as $2,000 for 39 courses in mathematics and science (Newsweek, February 14, 1983). The training is intensive and accelerated. Teachers may attain recertification in one or both areas of math and science. The college provides counseling to applicants in regard to their aptitude for mathematics.

A program description states:

The program is designed to provide intensive classroom and laboratory experiences in a compact time frame. All relevant Department of Education Certification Regulations, such as the requirement for an additional certificate, field of knowledge requirements, and practicum requirements have been adhered to carefully in order to assure a quality program.

The requirements for mathematics/science certification are as follows:

Course	Semester Hours
General Physics I and Lab	4
General Physics II and Lab	4
General Chemistry I and Lab	4
General Chemistry II and Lab	4
Geology	3
Environmental Biology and Lab	3
Biology of Organisms and Lab	4
Fundamental Concepts of Mathematics I	3
Fundamental Concepts of Mathematics II	3
Elementary Statistics	3
Calculus I	3
Computer Workshop	1
	39

As indicated above, the mathematics and mathematics/science programs consist of 39 semester hours. The mathematics/science certification program has been scheduled evenings and weekends, allowing many candidates to be certified within three academic semesters. The mathematics sequence is also an intensive one, requiring four semesters of intensive coursework.

The program description notes further:

> In addition to becoming certified by the Commonwealth of Massachusetts, each candidate has the option of applying for a Second Bachelor's Degree Program (a minimum of 30 credits must be taken at Westfield State College). Upon successful completion of the program, a Bachelor's of Science Degree in General Science and Mathematics is awarded.

Over 400 inquiries have been received from teachers across the Commonwealth of Massachusetts, resulting in more than 100 applications. Included among applicants to the program are: (a) teachers who are in fear of losing their jobs and want additional certification, (b) teachers who have already lost their public school positions, and (c) new young teachers who can't find an entry job in public school systems.

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A pretest has been designed for those students who may question their aptitude in the subject area. The pretest gives the student an opportunity in advance to discover whether such a change in discipline is appropriate for them, again ensuring quality participation.

In the few years of its existence, the program has proven successful. The math/science teacher retraining program was one of eleven in the nation to receive an award from the American Association of Colleges of Teacher Education. At least ten students who have graduated or who are nearing graduation have experienced success in finding positions in their new teaching field.

The main problem with the retraining program is that the students have a great deal of difficulty paying for the tuition, since many are unemployed or subemployed. It is unreasonable to expect those identified as best suited for the program (the unemployed or "RIF" teachers), to bear the burden of the cost alone, since they are least able to afford it. The College has adopted a deferred payment plan but most candidates still cannot afford the cost of retraining. The award from AACTE will help underwrite some of the program costs.

Proposals have been submitted to the Office of Postsecondary Education and the Fund for the Improvement of Postsecondary Education. If provided, the funding would be directed to train elementary teachers in the methodology of teaching mathematics and science, using available computer courseware and their own developed software. The Division of Graduate and Continuing Education hopes to expand the present program and develop new ones.

MATHEMATICS-SCIENCE TEACHER RETRAINING PROGRAMS IN OHIO

During the summer of 1983, the Ohio Department of Education and AEL sent surveys to the 49 teacher education agencies of the state. The purpose of the surveys was to identify the need for and existence of teacher retraining programs in the state. State education leaders see teacher retraining programs as a key to solving future shortages in mathematics and science. Separate surveys were sent to the heads of mathematics and science education programs. Response rates of 81 percent in mathematics and 63 percent in science were attained.

Three (8%) of the 40 responding institutions surveyed indicated that they plan to begin an out-of-field teacher retraining program in mathematics. In most cases, extensive planning has not yet been completed. Information provided over the telephone by each of the three institutions follows.

Ashland College has for some time discussed the possibility of instituting a mathematics teacher retraining program as part of their summer offerings. Such a program would be jointly administered by the College of Education and the mathematics department. Since the Mathematics Department faculty have recently begun to emphasize the development of new computer-related courses, they are not yet ready to undertake such a new initiative as a teacher retraining program.

Baldwin Wallace College personnel are interested in beginning a teacher retraining program in mathematics in 1983. Officials from the Jennings Foundation have expressed a willingness to work with Baldwin Wallace. However, area superintendents have said they do not expect a shortage of qualified mathematics teachers in the near future. So the planning of cooperative efforts for retraining has been suspended until a shortage of teachers is expected.

Kent State University officers are planning to begin a mathematics teacher retraining program in the summer of 1984, which they will continue year-round for a minimum of two years. The planning committee consists of the university provost and representatives from the college of education and the departments of mathematics and science. Kent State officials hope to obtain federal and state funding for the program, and to attract 90 candidates. They plan to have 30 people begin retraining at each of the three sites represented by the committee. The program is being publicized in nearby school districts. One official indicated that the impetus behind the retraining program is the concern about future mathematics teacher shortages and current large numbers of RIF'ed teachers in other subject areas. He believes that many of the RIF'ed teachers can be retrained to fill future mathematics positions.

Asked whether they would be willing to talk further about their planned or in-place teacher retraining program, eight of ten respondents answered in the affirmative. Only one of 40 respondents knew about out-of-field teacher retraining programs in mathematics sponsored by colleges or universities in the state of Ohio. The respondent noted that Wright State had such a one-year program for degree holders. Similarly, one of 39 respondents had heard of such programs in other states, but was unable to identify any institutional sponsor.

Twelve (39%) of 31 respondents said there was a need at their institution for an out-of-field teacher retraining program in mathematics. The 12 respondents represented the following 12 institutions:

- Notre Dame of Ohio
- Notre Dame of Ohio
- Bowling Green State University
- John Carroll University
- The Defiance College
- Ohio Northern University
- Central State University
- Denison University
- Denison University
- Ohio Dominican College
- University of Dayton
- Ohio University
- Bluffton College

Fifteen (58%) of 26 respondents said there was a need for an out-of-field teacher retraining program in mathematics in the state of Ohio.

Since most institutions did not have a mathematics teacher retraining program in place, success factors of such programs were not identified. However, one respondent expressed the opinion that the willingness of students to retrain and relocate would be essential to success. Another respondent expressed concern about whether prospective teachers would be willing to commit the required time to be adequately retrained.

A respondent who indicated there was a need for a retraining program at their institution also noted that the program should have high standards for admission and that it should not be open to all teachers. Two respondents said that their institution needed a teacher retraining program and expressed confidence that the mathematics department could staff the program, while one respondent said the mathematics department was understaffed and "could not handle a retraining program."

For the science survey, only one of the respondents indicated their institution would have a teacher retraining program in science. A Wright State University representative described by telephone their plans for a program in science.

Wright State University is located near Wright Patterson Air Force Base. For some time, representatives of the university and the base have wanted to begin a retraining program for military personnel who are leaving the Air Force through retirement to enter the private job sector. In the spring of 1984 a science education retraining program will begin. The Division of Teacher Education will administer the program. Through background analysis, the university has identified 170 people who, through

interest and ability, might qualify for the program. The university hopes to begin with a class of 20 to 25 people this spring and then start a second section later in the year. A student must finish five quarters and a student teaching experience in order to complete the program. The program will consist of essentially the same courses as the regular teacher education program, although they will be keyed to a more mature student. Since many of the prospective students have had experience living overseas, the program will include an emphasis on multicultural education. No special source of funding is anticipated.

None of the survey respondents knew of out-of-field teacher retraining programs in science, sponsored by Ohio colleges or universities. Similarly, not one respondent knew of such retraining programs outside the State.

Thirteen (76%) of 17 respondents indicated that there is a need at their institution for an out-of-field teacher retraining program in science. These respondents represented the following institutions:

- Mount Union College
- Urbana College
- Bowling Green State University
- John Carroll University
- Central State University
- Ohio Dominican University
- University of Steubenville
- Wright State
- University of Dayton
- Kent State University
- Findlay College
- Bluffton College
- Ohio Wesleyan
- Ohio University
- Capital University

Fourteen (58%) of 24 respondents said there was a need for an out-of-field teacher retraining program for science in the state of Ohio.

Of the respondents who indicated a need for a science teacher retraining program at their institution, one person said their institution had sufficient facilities, equipment and faculty to train excellent science teachers.

RECOMMENDATIONS

Four successful mathematics-science teacher retraining programs have been identified in this study. Each program differs from the others in important ways. For example, some retraining programs are full-time for one year, while others are part-time for as long as three years. Teacher education institutions initiate some of the programs, while local school districts initiate other programs. Still, some factors of success seem common to most of the programs. Since evaluation data are not available from any of the programs, the success factors have been identified through the program coordinators' attributions of program success.

All four of the programs were established on the basis of need in one or more local school districts of the surrounding area. The initiating agencies were able to identify the number of mathematics-science teacher vacancies in their own or nearby school districts. One institution of higher education with a teacher retraining program identified the number of eligible teachers through recent statistics on reductions in the teaching force. Successful programs, then, were designed to meet existing needs and were to continue only as the need continued.

Respondents noted that the program would be successful, if they carefully selected both the teacher-trainees and the university instructors. For example, two local school districts emphasized the importance of selecting teacher trainees who were mature and who had sufficient aptitude to become a mathematics or science teacher. The mature teacher was seen as a good candidate for retraining because they already were proven capable of classroom management and of maintaining discipline. With the mature teacher, training efforts could be concentrated on teaching content and methods.

Some programs used aptitude tests for identifying candidates. Since program dropouts were identified as those teacher-trainees who were not required to have high aptitude test qualifying scores, successful programs then required a high score on the test.

One local school district indicated that it is important to identify suitable university instructors for participation in the program. Respondents from successful programs emphasized that instructors should have adequate mastery of the content and should be accomplished teachers. Most of all, the instructor should be known to have the ability to relate comfortably with the adult learner.

While either a local education agency or an institution of higher education may initiate the retraining program, successful program respondents said it is important that the initiator assume continuing responsibility for the program coordination. One school district said this required the coordinator to assume a nurturing role in regard to the success of the program participants. Some respondents thought that this might avert a high dropout rate.

Relatedly, it is important for all participating agencies to establish and maintain close working relationships. It was suggested that this might be facilitated by having one person from each agency responsible for its participation in the program. One local school district found it helpful for a central office administrator to teach one of the program courses at a participating university. It was said that this provided the district with realistic information about the teacher-trainees' experience.

One school district emphasized the importance of establishing a class of teacher-trainees, if possible, and keeping them together throughout the program. All participants would take the same courses together as they

progress through the program. The advantages of this approach are that it builds esprit de corps, provides a support group, and builds a group problem-solving capacity.

The same school district said it is essential for a successful program to provide trainees with opportunities to observe capable, experienced mathematics-science teachers in the classroom. Another district emphasized that it is necessary to provide teacher-trainees with gradual experience in practice teaching, beginning with the least difficult mathematics courses, and proceeding to more difficult courses.

An institution of higher education providing teacher retraining in mathematics indicated that the ideal retrainees (unemployed or under-employed teachers), have insufficient financial resources to afford the program. They pointed out that successful programs used to subsidize tuition costs with money available through federal funding sources.

One local education agency with considerable financial resources has designed what amounts to a very sophisticated merit pay program as an incentive for teacher retraining. This district has found the financial incentive to be a very successful motivator for teachers to seek retraining. Stipends are provided to teachers who seek retraining. Higher stipends are provided for retraining for positions where there are more critical teacher shortages (mathematics and science in inner city schools.)

In summary, successful programs were established on the basis of the need for mathematics and science teachers in local school districts; they carefully selected teachers and trainers; they attended to progress of program participants; they had interagency cooperation; they provided experience in practice teaching; and they subsidized tuition cost with federal funding sources.